ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

Report On

PROJECT NO. 14 - METHODS OF PROTECTION AGAINST FLASH BURNS

Project No. 14 INFORMATION COPY 13 November 1943

ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. 14
710 GNOML

13 November 1943

1. PROJECT: No. 14 - Methods of Protection Against Flash Burns.

a. Authority - See Appendix A.

b. Purpose - To describe means of protecting against flash burns in tanks and to report the results of test of a protective cream.

2. DISCUSSION:

Reports from combat theaters indicate that a signficant number of casualties among tank crews are the result of burns; in some reports, the proportion being as high as 20%. These burns are suffered before and during evacuation from the tank which is set on fire during combat. A smaller proportion occurs outside, from the handling of and cooking with gasoline. Within the tank, burns may be caused by:

a. Explosion of a penetrating charge.

b. Burning gasoline, oil, rags, etc.

c. Burning of the propellent in stowed ammunition.

Of these causes, the third, c, is of greatest importance; experience indicates that over 90% of tank fires initiate from burning propellent ignited by hot fragments of projectile or armor which tear shell cases. A record of the temperatures produced in tanks from burning ammunition and a discussion of the temperatures necessary to produce burns are given in Appendix B. It has been generally noted that, without regard to the origin of the fire, the temperatures developed are limited to such levels, that burns occur only on exposed skin surfaces and that the protection given by fatigue clothing or underclothing is sufficient for the time required in evacuation of the tank. The period for escape is brief. Most observers agree that all men who will escape from the tank do so in from 3 to 5 seconds after the beginning of the fire. The burns that they suffer are usually 1st and 2nd degree, although superficial 3rd degree burns occasionally occur. Clothing may be ignited but is usually readily extinguished after evacuation.

Since the initial burns in tanks are of the flash type and since the measure of protection afforded by a layer of clothing is adequate for

the short time required in evacuation, special attention has been directed to various means of protection of the exposed surfaces. Extra flaps on the sleeves of garments, and face and neck shields designed to be suspended from the helmet, have all been considered. Such attachments have not found favor because they interfere with activity in the tank and add to the heat load imposed by the uniform.

The application of ointment before combat for the purpose of protecting exposed skin has long been the practice in the Navy, and, for this purpose an improved film-forming ointment has been developed by the Naval Medical Research Institute. Supplies of their material were provided the Armored Medical Research Laboratory for study with special reference to its use by tank crews. The results of laboratory and field test with the material are given in Appendix C. Some general notes on the nature and characteristics of the cream and the method of application are presented in Appendix D.

Consideration has also been given the use of methods of reducing flammability of clothing, not so much from the point of view of increasing the duration of the protection within the tank but rather to eliminate after-burning subsequent to ignition. Discussion of the possible usefulness of flame-retardant materials and results of tests of their behavior are given in Appendix E.

3. CONCLUSIONS:

a. Tank fires are a frequent cause of casualties.

b. Temperatures in tanks during ammunition or fuel fires may reach levels of from 1000 to 2700°F in from 10 to 30 seconds.

c. An exposure of approximately 2000 degree-seconds will cause 2nd degree burns.

d. The time required for escape from tanks is from 2 to 5 seconds.

e. Tank crews require protection from flash burns for an interval sufficient to permit evacuation.

f. Regulation fatigue or combat clothing is adequate to protect the covered parts against the initial flash for the time necessary for escape. This protection is markedly increased if the garment is wet with perspiration.

g. It is desirable that clothing be made fire-resistant but the treatment should be such that it will not impose excessive heat load upon the wearer, be irritating or give off toxic or nauseous fumes.

h. Some method of protection of the exposed skin is necessary.

i. On the basis of the laboratory tests, the use of protective cream will prevent flash burns of the exposed skin for the period required for evacuation.

j. The protective cream is easily applied and does not interfere with the functions of the crew. It need be applied only before going into combat.

k. Protective cream is impractical at extremely high temperatures and humidities where sweating is profuse because it is gradually washed off by sweat.

l. At least two (2) quarts of water are required for removal of the film; it may, therefore, be impractical for use where the supply of washing water is extremely limited. The film may, however, be left on for several days without ill effect.

m. The cream in tin packages is not damaged by extremes of temperature.

4. RECOMMENDATIONS:

a. That the protective cream described in Appendix D be procured for immediate issue to tank crews in combat areas.

b. That a 5-day supply (10-4½ oz. cans) be carried as part of regular stowage and that issue be established to maintain this supply. If used daily, 2/cans/crew/day are required.

c. That instructions be issued regarding use of the protective cream. (See Appendix F)

Prepared by:

Lester B. Roberts, Major, Sn C
Wendell E. Mann, 1st Lt., MAC

7 Inclosures
#1 - Appendix A , Authority
#2 - Appendix B
Tank Fires and Burns
In Tanks
#3 - Appendix C, Tests of Flash-Burn
Preventive Cream
#4 - Appendix D, General Observations and
Application
#5 - Appendix E, Flame-Resistant or Fire-Retardant
Clothing
#6 - Appendix F, Application and Removal of Preventive
Flash Burn Cream
#7 - Photos

APPROVED Willard Machle
WILLARD MACHLE
Colonel, Medical Corps
Commanding

ARMORED [redacted] MEDICAL RESEARCH LABORATORY
FORT KNOX, KENTUCKY

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400.112/6 GNOML 25 September 1943

SUBJECT: Request for Approval of Project

TO : Commanding General, Headquarters Armored Command, Fort Knox, Kentucky.

1. In some operations, burns of the exposed surfaces have caused as high as 20 or 25% of the casualties in tank crews. Skin protected by clothing usually escapes flash burning.

2. The need for protection of the face and hands is recognized. Preliminary investigation indicates that certain films or ointments which can be applied before combat will protect these areas from flash burns.

3. Request approval of Project "Investigation of Methods of Protection Against Flash Burns".

/s/ Willard Machle
WILLARD MACHLE
Colonel, Medical Corps
Commanding

700.2/1 (25 Sep 43) GNOHD 1st Ind.

HQ ARMD COMD, Ft Knox, Ky, 1 Oct 43.

To: CG, AGF, AWC, Wash, DC.

Recommend approval.

For the Commanding General:

/s/ E. R. Gray, Jr.
E. R. GRAY, JR.
Major, A. G. D.
Asst. Adjutant General

APPENDIX A

RESTRICTED

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720 (25 Sep 43)
GNRQT-10/56412 2nd Ind.

HEADQUARTERS ARMY GROUND FORCES, Army War College, Washington, D. C.
13 OCT 1943

TO: Commanding General, Armored Command, Fort Knox, Kentucky.

1. Approved.

2. It is understood that this project is for the purpose of modifying the ointment developed by Captain Hakassan, U. S. Navy, to meet the conditions encountered in tanks.

By command of LT. GEN. McNAIR:

/s/ R. J. Delacroix
R. J. DELACROIX
Major, A.G.D.
Asst. Ground Adj. Gen.

700.2/1 (25 Sep 43) GNOHD 3rd Ind. S - 15 Nov 43.

HQ ARMD COMD, Ft Knox, Ky, 16 Oct 43.

To: CO, Armd MRL, Ft Knox, Ky.

1. Attention is invited to preceding indorsement.

2. Project on "Method of Protection Against Flash Burns" will be initiated as soon as possible.

By command of Major General GILLEM:

/s/ E. R. Gray, Jr.
E. R. GRAY, JR.
Asst. Adjutant General

APPENDIX A

TANK FIRES AND BURNS IN TANKS

1. Characteristics of Fires.

Tests were carried out to determine the time of onset, rate of rise, peak temperatures and duration of ammunition fires in tanks. In addition, opportunity to measure temperatures was had during a test of susceptibility of tanks to fires. Observations on three fires in the same M4 tank were made. Details of test conditions, methods and results are given in the attached protocols and in Figure 1.

Description of Tests

Tests were carried out from 1400 to 1700 hours, 26 February 1943, Salt River Range No. 1. Temperature 30°F. Wind on starboard beam of target tank. Velocity variable, 0 to 15 mph. Weather overcast, heavy driving snow at times with clear and bright intervals. The test vehicle was an M4A4 tank, welded hull vehicle stripped and transmission removed. Placemant and type of ammunition given in individual test descriptions.

Observations were made from a tank O. P. 105 feet from target tank. Temperature recordings with chromel-alumel thermocouple, Rubicon potentiometer, cold junction buried in ground 15 feet from tank. There was approximately a 2-second lag in instrumentation and recording.

TEST #1

Port sponson and port turret racks stowed with 75 mm APC M61. Thermocouple at position of loader's chest. 37mm APC fire through turret. Fire was instantaneous, 2 casings burned out. Temperatures are given in Curve 1, Figure 1. No water used.

TEST #2

Port sponson and port turret racks stowed with 75 mm APC M61. 75 mm AP through turret. Fire started somewhat more slowly. Thermocouple in position of gunner's chest (to starboard). Temperatures given in Curve 2, Figure 1. Water was turned on as soon as fire was noted.

TEST #3

HE M48 in starboard sponsons. 75 mm APHE through forward sponson rack, strewing ammunition over floor in bow. Thermocouple in position of driver's chest. Temperatures given in Curve 3, Figure 1.

No generalizations on the effects of ammunition fires on tank crews are possible from these tests. It is evident, however, that the effects upon various members of the crew will be determined by the number of rounds that are ignited, the size of the rents in the casings, and the location of the fire in relation to the man or to the openings for escape.

Air temperatures during the fire were of such an order that a considerable measure of protection would have been afforded the crews by ordinary clothing and gloves.

Two variables were introduced into the test, viz., the use of water in two tests and the presence of openings in the tank. With these not operating the fires may have behaved differently.

2. Temperatures Reached in Tank Fires.

Observations included measurement of both the maximum temperature and the rate of increase of temperature from the fires which developed when the armor of the tank was penetrated and stowed ammunition ignited. The following conclusions were arrived at: The rate of temperature rise is variable. It may be either very slow (peak reached within ½ minute or more) or practically instantaneous. In three (3) tests ambient air temperatures of 700-900°F were reached in from 20 to 25 seconds after ignition. Temperatures capable of causing flash burns occurred within 1½, 3½ and 20 seconds during three separate tests. A number of factors influence both the rate of temperature rise and the final peak temperature. These included:

a. Type of projectile entering tank.

b. The ventilation within the tank, i.e., whether hatches are open or the tank buttoned up. Size of the hole made by entering projectile.

c. Type of ammunition and quantity ignited.

d. The location and arrangement of ammunition ignited.

From information obtained by observers and men who have escaped from burning tanks it is generally believed that a period of not more than five (5) seconds is available for escape between the time of penetration of the tank by the projectile and the time when lethal temperatures will occur within the tank. The effects upon the individual members of the crew will be determined by the location of the ignited ammunition, its type, the number of rounds and the presence of drafts and chimney effects with reference to location of the openings used for escape.

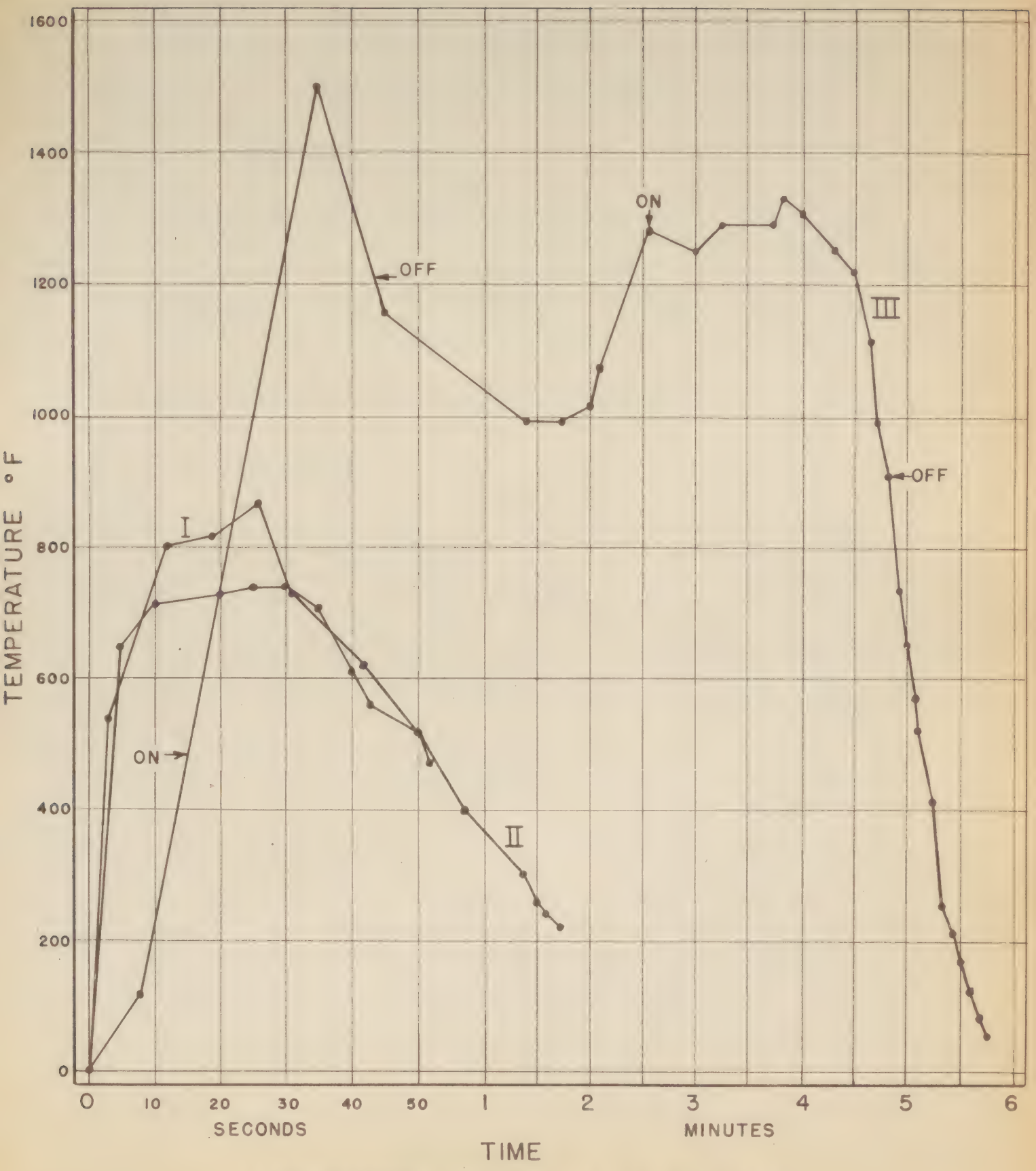
3. Temperatures Necessary to Produce Burns.

Most information concerning the temperatures necessary to produce burns have been obtained from studies with comparatively low temperatures acting for relatively long periods of time, together with some data on

flash burns. It is generally agreed that two elements determine the severity of the burn, these are: (1) the time of exposure to the high temperature and (2) the temperature level. Some variation will be introduced by the moisture content of the air and wetness or dryness of exposed skin surfaces. Extreme variations are introduced when the burn results from exposure to metal instead of exposure to hot air. Furthermore, damage to the respiratory tract may be produced by the inhalation of hot air or of hot gases. A rough estimate of the time-temperature relationship which will be effective in producing second degree burns is given in the following table:

Time of Exposure	Temperature °F
Less than 1 sec. (flash)	2000°F +
3 seconds	700 - 900°F +
15 seconds	212°F
30 - 60 seconds	160 - 180°F

These values hold good for air, whereas, the heat damage of water, either very hot or scalding, or metal will be produced with shorter exposures and at lower temperatures. Plot of the above data indicates that for these ranges of temperature and time, 2nd degree burns will be produced by a constant value which is the product of time and the difference between the air and skin temperatures. For purposes of rough calculation this value may be taken to be 2000 degree-seconds.



AMMUNITION FIRES IN M-4 A-4 TANK

FIG. I

APPENDIX C

TESTS OF FLASH-BURN PREVENTIVE CREAM

1. Laboratory Tests.

Both animal and human subjects were used at the Naval Medical Research Institute to determine the ability of the cream to protect against flash burns and to establish its optimum composition. A flash gun capable of producing a severe burn on the shaved skin of rabbits or the human forearm was used. The estimated temperature of the flash was above 1800°F; the exposure time less than one (1) second. The flash cream gave complete protection when tested under these conditions.

A series of tests at this laboratory showed that the film gave complete protection for the human skin at 1500°F for an exposure time of 3 seconds.

2. Field Tests.

Six (6) tank crews were supplied with protective cream which was worn all day during combat practice operations. These included cross country driving "buttoned up" and opened, simulated firing, mounting and dismounting and general combat maneuvers. It was established from these tests that there is no difficulty in applying the cream, and there is no interference with normal operation or comfort of the crew. Most importantly, the test showed a willingness of the men to use the cream. Particular importance may be attached to this last consideration because, under battle conditions, it will undoubtedly be the individual's decision whether or not he will wear the cream.

The inclosed photos were taken during the tests. They illustrate certain of the points discussed herein.

GENERAL OBSERVATIONS AND APPLICATION

Description

The Protective Flash Burn cream is supplied in small ointment cans, each containing sufficient cream for an application to the face, neck and hands for two crew members with sufficient excess for touching up, as required. The cream in the container is similar in body to a heavy theatrical-type face cream and is about as easily applied. It is recommended that sufficient cream be applied so that the skin surface does not show through. Thicker application will give additional protection. After application, the cream sets or dries in a few minutes forming a flexible film. It retains its flexibility but loses all tackiness, leaving the film dry to touch. During the short drying period there is generally a slight drawing sensation from the film.

It is impractical to apply the cream on eyelids and immediately around the eye (see photos). Protection is, therefore, not afforded these areas.

The dried film does not pick up dust and dirt or become grimy. Not being tacky, it is not left on objects touched. The film will be removed by continued rubbing or abrasive wear. In the case of tank drivers and gunner, the film is soon worn from the palm of the hand and insides of the fingers. Normal perspiration is not interfered with by the applied film nor does normal perspiration make the film run or become tacky. However, profuse sweating as might be expected at extreme temperatures and high humidities will cause the film to soften and come off easily. Accordingly it is not recommended that the cream be used under these conditions. The cream resists water such as is encountered in a drizzle or moderate rainstorm and has not run off or become tacky for short intervals in hard driving rain. It has not, to our knowledge, been tried for extended periods in severe driving rain. A special cream can be compounded to resist running, even under the severest sweating or rain conditions; however, such a cream would be difficult to remove. The regular cream contains a detergent which facilitates removal when used with soap and water. In combat theaters where washing water is scarce, the desirability of removal will have to be balanced against the protection afforded, to determine if and how the cream shall be used. Removal requires brisk scrubbing with soap and water but is not difficult. Gasoline, benzine or other solvents are not required or recommended for removal. The cream does not contain allergens or toxic ingredients. Composition of the cream and description of the components are given in Table 1.

Burn Protection

The ability of the cream to protect against flash burn has been determined by the Naval Medical Institute. Using the same type apparatus

and procedures, we have established that the cream will protect against the type of flash burn which occurs in tanks. A program has been established to appraise quantitatively the degree of protection but it is felt that recommendations should not await the completion of the program since the data at hand is sufficient to warrant immediate use of the material in combat areas.

TABLE 1

COMPOSITION OF FLASH-BURN PROTECTION CREAM

	%	Purpose
Shellac	13.70	film - binder
Isopropanol 99%	28.48	solvent
Linseed Oil Bodied	3.50	plastercizer
Stearic Acid	.15	inter lubricant - for manufacture
Flexol	.80	plastercizer
Carbitol	1.10	solvent
Titanium dioxide	37.00	insulator
Sodium Bicarbonate	2.25	to make alkaline
Magnesium Sterate	8.00	lubricant
Methyl Salicylate	2.50	light screen
Dupanol	.30	wetting agent
*Mineral Black	2.22	shading

* The flat color of the film is excellent camouflage .

FLAME-RESISTANT OR FIRE-RETARDANT CLOTHING

Since a large number of casualties from burns are of the flash variety, the utilization of flame-retardant clothing, in combination with anti-flash ointment suggests itself as an important protective measure in tank operations. An additional degree of protection may be obtained from the protection against actual burning of the fabric of the garments worn by the soldiers. The experience of the Navy and armored units in combat is that flash burns of a serious nature are prevented by ordinary clothing. This protection is greater when the clothing is wet than when dry. In the experimental fires produced in the M4A4 tank at Fort Knox, all or most of the crew might reasonably be expected to escape from the tank in two of the three test fires. In the third, the bow crew would not have been directly affected and two of the turret crew could have probably escaped with minor burns. The loader even if he had escaped would however, have been very badly burned.

Fire-proofing of cotton and woolen fabrics has been standard practice for many years. Most of the methods which have been used to impart fire-resistance to draperies and curtains in theaters, etc., have depended upon water soluble salts (phosphates, borates and sulfamates) because resistance to laundering and dry cleaning was not essential. Tin compounds have also been used, especially in the form of tungstate. The ideal requirements for a satisfactory fire-resistant treatment would include (1) fire-resistance (2) satisfactory withstanding of laundering or dry cleaning without loss of fire-resistant qualities, (3) porosity similar to that of untreated fabrics (4) tensile qualities similar to that of untreated fabrics.

Insofar as the fire-proofing of clothing is concerned, it is obvious that water soluble materials will not serve the purpose where repeated laundering is necessary unless facilities for renewal of impregnation are made generally available. The next attack on the problem has been use of water insoluble salts either impregnated into or precipitated on the fabric. Of many materials tested, antimony oxychloride has the best fire-resistant qualities but is difficult to fix to the cloth or fabric and is relatively unstable, in addition to being decomposed by ultra-violet light with the liberation of hydrochloric acid. The same properties of fire-resistance are obtained if antimony and chlorine are added to the fabric separately instead of in a single chemical compound, for example, antimony oxide plus a chlorinated hydrocarbon such as the chlorine-containing vinylites. Cloth treated in this way has shown satisfactory fire-resistance in a number of tests and also has retained these qualities after repeated launderings. Preliminary tests in the laboratory hot room have indicated that on the man doing protracted exercise, fire resistant suits impose a slight, but definite and measureable heat burden, resulting in a higher pulse rate

and high rectal temperature and increased sweat rate when compared with men working in an unlaundered uniform of the same fabric and cut. Further tests will determine whether this disadvantage persists after repeated launderings.

APPLICATION AND REMOVAL OF PROTECTIVE FLASH BURN CREAM

Instructions on the label of each can to read: "Directions - Cover all exposed skin (face, neck, hands, arms) with thin layer of cream so that the skin does not show through. The cream will dry within five minutes and protect against ordinary flash burns. Reapply if film is thinned by perspiration or rain. To remove, wash thoroughly with soap and water, rubbing well."

These directions are self-explanatory and sufficient if followed. Removal is expedited by the use of plenty of soap.

The time of application is immaterial so long as the men have the cream on in action. It may be applied by the man using it or the men can apply it to one another.

Project No. 14
11/13/43

APPLYING FLASH-PROTECTING CREAM

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11/13/43

PROTECTIVE CREAM AFTER APPLICATION

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11/13/43

REMOVING CREAM

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REMOVING CREAM

ARMORED MEDICAL RESEARCH LABORATORY - FORT KNOX, KY.

Project No. 14
11/13/43

AFTER REMOVAL OF CREAM

ARMORED MEDICAL RESEARCH LABORATORY - FORT KNOX, KY.

2392